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Dissolution of alumina ceramics in HCl aqueous solution

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Abstract

Dissolution of a cold isostatically pressed high purity alumina ceramics in aqueous HCl solutions was studied as a function of immersion time and acid concentration. From the amounts of Al^{3+}, Mg^{2+}, Ca^{2+}, Na^{+}, Si^{4+} and Fe^{3+} ions released in the corrosive solution, a degree of dissolution χ_i for each component was calculated according to the equation $\chi_i = A/B$, where A and B are respectively the amount of the element released in the corrosive solution and the amount of the element in the untreated material. The determination of the amounts of ions released in the corrosive solutions was carried out by means of atomic absorption spectrometry (AAS). The corrosion of alumina ceramics in the HCl aqueous solution is determined by the solubility of alumina and the solubility of grain-boundary impurities. Very low dissolution values of Al^{3+}, Mg^{2+}, Ca^{2+}, Na^{+}, Si^{4+} and Fe^{3+} ions after the corrosion test of alumina ceramics showed a very good corrosion resistance in the HCl aqueous solution.

Keywords: C. Corrosion; Alumina ceramics; Degree of dissolution

1. Introduction

Aluminium oxide, Al_2O_3, more often referred to as alumina, is an exceptionally important ceramic material, which has many technological applications [1,2]. It has several special properties like high hardness, chemical inertness, wear resistance and a high melting point. Because of their excellent properties, alumina ceramics are widely used for many refractory materials, grinding media, cutting tools and high temperature bearings. Therefore a wide variety of mechanical parts, and critical components in chemical process environments where materials are subjected to aggressive chemical attack, increasingly higher temperatures, and pressures.

The surface dissolution of these ceramic materials is basically good, but it may be influenced by many factors, such as the composition and microstructure of the ceramic material, the chemical character of the corrosive medium, the exposure time and the temperature. In the presented work, the degree of dissolution of high purity alumina was investigated at room temperature for 10 days in HCl solutions of different concentrations. All investigations showed that the corrosion resistance of alumina ceramics is influenced by the purity of the material due to the segregation of impurities to the grain boundaries during the sintering process. It is well known that alumina ceramics consist of α-Al_2O_3 grains and intergranular phases, such as silica compounds, and a glass phase. Dopants and impurities often segregate to grain boundaries and may cause the formation of an amorphous or crystalline phase and/or may change the local defect chemistry. If the ceramic has very high impurity content, a crystalline or amorphous grain-boundary phase is formed and intergranular attack in aqueous acidic solutions can be expected [3–5]. Several researches have reported the selective dissolution of the grain-boundary phase [6–9].

2. Materials and methods

The material used in corrosion tests in HCl solution was a cold isostatically pressed (CIP)-Al_2O_3 with a purity of 99.8%. The samples were sintered in a gas furnace at 1650 °C. The Archimedes density of the CIP-Al_2O_3 was 3.91 g/cm^3. The chemical composition of investigated alumina ceramics, according to manufactures declaration is shown in Table 1. The CIP-Al_2O_3 specimens were supplied by Applied Ceramics, Inc., Fremont, CA, U.S.A. Al_2O_3 ceramics contains MgO as a

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Table 1
Chemical composition of the Al_2O_3 ceramics.

Sample	Alumina ceramics
MgO (wt.%)	0.066
Fe_2O_3 (wt.%)	0.015
SiO_2 (wt.%)	0.02
Na_2O (wt.%)	0.05
CaO (wt.%)	0.013
Al_2O_3 (wt.%)	Rest

sintering aid and the usual impurities, i.e. SiO_2, CaO, Na_2O and Fe_2O_3.

After sintering, specimens were cut into rectangular coupons with the size of 0.8 cm × 1.0 cm × 2.0 cm. Each surface of Al_2O_3 specimens was polished to 1.5 μm. After polishing and before corrosion tests, samples were thoroughly cleaned with alcohol and dried in a sterilizer (Instrumentaria, Zagreb, Croatia) at 150 ± 5 °C for 4 h. These specimens were then used for corrosion testing. In the HCl corrosion tests, the specimen and 5 ml of an HCl solution were put into a sealed polypropylene (PP) tube. Samples were completely immersed in the solution. The corrosive environments were HCl solutions, with concentrations of 2, 10 and 20 wt.%. In parallel with corrosion testing, a blind test was also performed. The corrosion tests were carried out at room temperature (25 °C) from 24 to 240 h. To avoid an enrichment of leached components at the surface of samples, the solution was occasionally stirred. After the planned exposure time, the specimens were removed from the tubes, rinsed with boiling distilled water, and dried in a warm heated oven at 150 °C. For each experimental condition, five tests were performed simultaneously.

The amounts of Al^{3+}, Mg^{2+}, Ca^{2+}, Na^{+}, Si^{4+} and Fe^{3+} ions dissolved in the corrosive solutions were determined by means of the atomic absorption spectrophotometry (AAS, AA-6800, Shimadzu). All data were averages of five values. The measurements were conducted after 24, 48, 72, 120, 168 and 240 h of immersion.

3. Results and discussion

During corrosion testing, the mass of specimens remained unchanged (it was measured on an analytical balance with the degree of precision of 10^{-5} g). Mechanisms responsible for corrosion processes were observed by determining the amount of ions released in the corrosive solution.

Fig. 1 gives the amount of Al^{3+}, Mg^{2+}, Ca^{2+}, Na^{+}, Si^{4+} and Fe^{3+} ions eluted from the alumina ceramics in dependence on the exposure time in different mass concentrations of hydrochloric acid. All data presented in Fig. 1 are averages of five values; therefore error bars are plotted. On the basis of

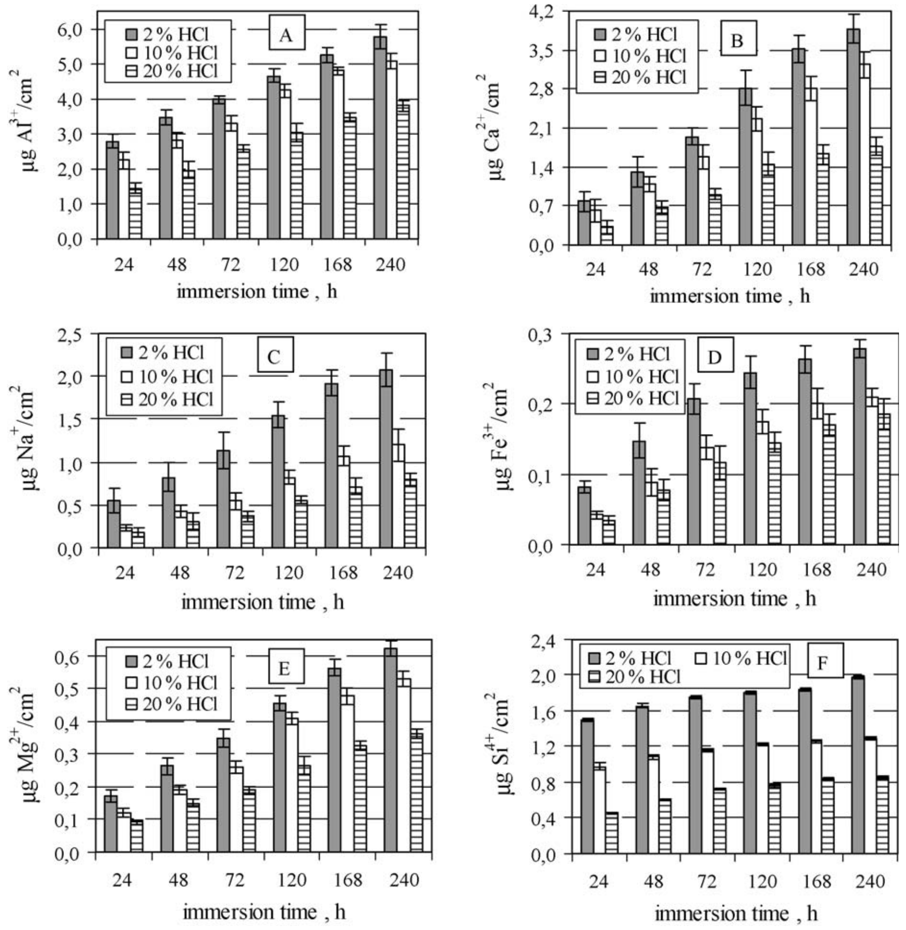

Fig. 1. The amount of Al^{3+} (A), Ca^{2+} (B), Na^{+} (C), Fe^{3+} (D), Mg^{2+} (E) and Si^{4+} ions (F) in the eluate as a function of immersion time from corrosion tests in 2% HCl, 10% HCl and 20% HCl (mean value and standard deviation).